# NOISE EXTRACTION USING FREQUENCY DOMAIN ANALYSIS

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## ABSTRACT

Noise is considered a hindrance in every vibrations signals including in an automotive suspension systems. Therefore methods of noise extraction were introduced in order to extract noise in the vibration signals. In this study noise are extracted from an automotive suspension system by frequency domain analysis. The vibrations frequency of the automotive spring is set to 8 Hz, 9 Hz and 10 Hz after that the automotive spring vibrations signals data were collected by using an accelerometer which connected to the suspension test rig which it functions were to measure the displacement of the spring, by using DASYLab® software. The vibrations signals it is then undergoes a low pass and high pass filter which is then interpreted in the form of power spectrum density which is done by fast-Fourier transforms which is then from the power spectrum density it is analyze to conduct noise extraction. The result is based on the ripple produce in power density spectrum of all the different frequency and also a different low-pass filter and high-pass filter. After that finding the most suitable frequency conditions for the low pass and high pass filter based on power spectrum density produce after filter process. The most optimum condition for noise extraction which achieved the most free noise vibration is when the low-pass filter is set to a frequency of 8 Hz and the high-pass filter is set to a frequency of 10 Hz.

# ABSTRAK

Bunyi hingar dianggap sebagai penghalang dalam setiap isyarat getaran termasuk dalam sistem suspensi automotif. Oleh itu, kaedah pengekstrakan bunyi hingar telah diperkenalkan untuk mengeluarkan bunyi hingar di dalam isyarat getaran. Dalam kajian bunyi hingar ini, ia diekstrak daripada sistem suspensi automotif melalui analisis frekuensi domain. Kekerapan getaran automotif spring ditetapkan diantara 8 Hz, 9 Hz dan 10 Hz, selepas itu isyarat data getaran automotif spring dikumpulkan dengan menggunakan meter pecut yang disambungkan ke suspension test rig yang berfungsi untuk mengukur sesaran spring, dengan menggunakan perisian DASYLab®. Kemudian isyarat getaran melalui proses penapisan lulus rendah dan laluan tinggi yang kemudiannya diterjemahkan dalam bentuk ketumpatan kuasa spektrum yang dilakukan oleh jelmaan Fast Fourier, kemudian dari ketumpatan kuasa spektrum ia akan dianalisis untuk mendapatkan pengekstrakan bunyi hingar. Hasil kajian ini adalah berdasarkan kepada kekerapan dalam ketumpatan kuasa spektrum untuk kesemua frekuensi yang berbeza dan juga kepada penurasan laluan rendah dan laluan tinggi yang berbeza. Selepas itu, usaha untuk mendapatkan keadaan frekuensi yang paling sesuai untuk penapisan lulus rendah dan lulus tinggi berdasarkan kepada ketumpatan kuasa spektrum yang dihasilkan selepas melalui proses penapisan. Keadaan yang paling optimum bagi pengekstrakan bunyi hingar yang telah mencapai bunyi getaran paling bebas ialah apabila penapisan laluan rendah ditetapkan pada frekuensi 10 Hz dan turas laluan tinggi ditetapkan frekuensi 8 Hz.

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# LIST OF SYMBOLS

| | |
|---|---|
| $\omega$ | Natural frequency |
| *CF* | Crest Factor |
| $M_3$ | Moment of Stage-3 |
| $M_4$ | Moment of Stage-4 |
| $N$ | Number of data |
| *r.m.s* | Root Means Square |
| *SD* | Standard Deviation |
| $t$ | Time |
| $\bar{x}$ | Means |
| $x_i$ | Initial Value |
| $X$ | Amplitude |

# LIST OF ABBREVIATIONS

| | |
|---|---|
| DFT | Discrete Fourier Transform |
| FFT | Fast Fourier Transform |
| IDFT | Inverse Diverse Fourier Transform |
| IFFT | Inverse Fast Fourier Transform |
| PSD | Power Spectral Density |

# CHAPTER 1

# INTRODUCTION

## 1.1. INTRODUCTION

Noise is defined as any unpleasant or unexpected sound created by a vibrating object. Noise are present in every moving object and considered a hindrance and unwanted data therefore noise are usually neglected when performing vibration analysis.

Vibration is an oscillation wherein the quantity is a parameter defining the motion of a mechanical system. Oscillation is the vibration, usually with time, of the magnitude oa a quantity with respect to a specified reference when the magnitude is alternately greater and smaller the reference. More often, vibration is undesirable, wasting energy and creating unwanted sound (noise). For example, the vibrational motions of engines, electric motors, or any mechanical device in operation are typically unwanted. Such vibrations can be caused by imbalances in the rotating parts, uneven friction, the meshing of gear teeth, etc. Careful designs usually minimize unwanted vibrations.

A signal is a real (or complex) valued function of one or more real variable(s). When the function depends on a single variable, the signal is said to be one dimensional. Signal is a series of numbers that come from measurement, typically obtained using some recording method as a function of time. A signal can be extracted from many sources such as vibrating machines, sound and movement.

Vibration signal is present in all moving object whether it is rotating or translating. The motion of a mechanical system can consist of a single component at a single frequency as with the system or it can consist of several components occurring at different frequencies simultaneously, as for example with the piston motion of an internal combustion engine. The motion signal is here split up into its separate components both in the time domain and in the frequency domain.

## 1.2. PROJECT BACKGROUND

Frequency domain signal analysis covers a wide variety of techniques involving the Fourier transformation of the signal. The signal's frequency domain representation is then manipulated, decomposed, segmented, classified, and interpreted. One central idea is that of a filter, that is a linear, translation-invariant system that allows one band of frequencies to appear in the output and suppresses the others. Where signal elements of interest occupy a restricted spectrum, filters invariably enter into the early processing of candidate signals. In other ways often purely theoretical frequency-domain analysis is important.

Unit of measure for frequency is called Hertz and it is equivalent to 1 cycle per second. So if the time it takes for a wave to pass is 1/2 second, the frequency is 2 per second. If it takes 1/100 of an hour, the frequency is 100 per hour. The Figure 1.1 and Figure 1.2 below show the different frequency of wave.

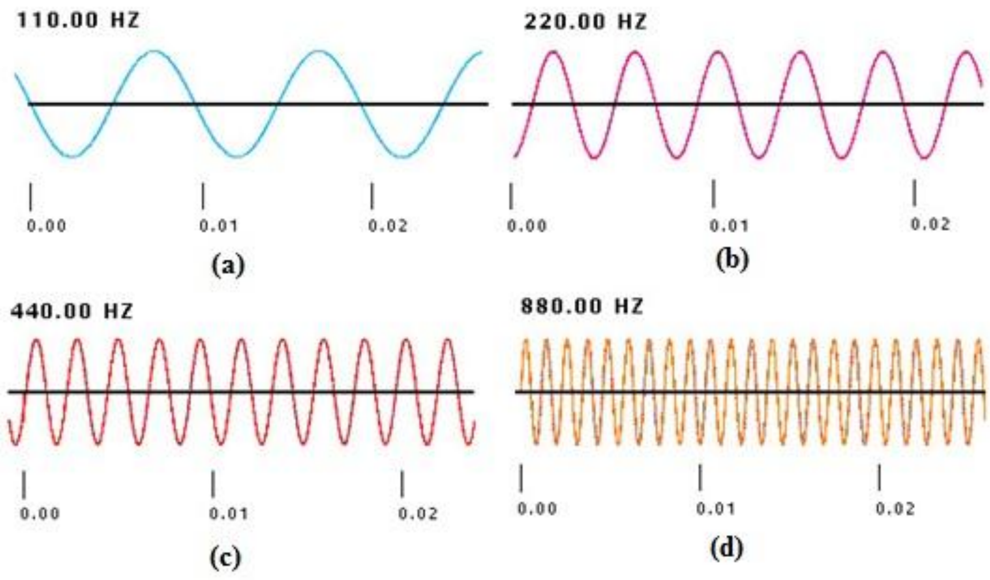


**Figure 1.1:** The wave of frequency. a) 110 Hz, b) 220 Hz, c) 440 Hz, d) 880 Hz

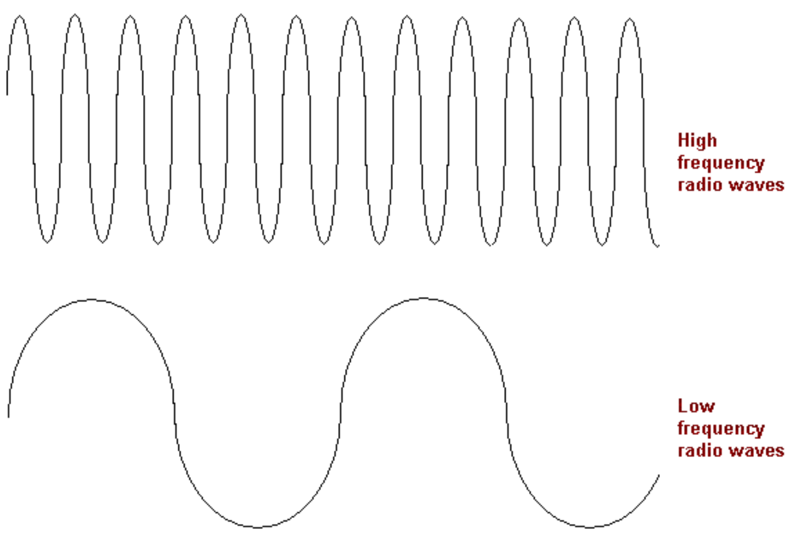


**Figure 1.2:** Example of the different frequency of wave

## 1.3. PROBLEM STATEMENT

Noise presence in any signal is the common phenomenon during recording the data. This noise can be considered unwanted data without meaning that is, data that is not being to transmit a signal, but is simply produce as an unwanted by-product of other activities. A method is known as noise extraction can be apply to eliminate noise in order to reduce analysis time, but at same time produce the similar results as the original signals. Thus, it is a critical requirement to optimize the noise value (in term of power) that should be eliminating to provide an accurate result.

## 1.4. OBJECTIVE

The objectives of this study are:

i. To extract noise from the vibration signals.
ii. To perform statistical analysis.

## 1.5. HYPOTHESIS

A time domain graph shows how a signal changes over time, whereas a frequency domain graph shows how much of the signal lies within each given frequency band over a range of frequencies. A frequency-domain representation can also include information on the phase shift that must be applied to each sinusoid in order to be able to recombine the frequency components to recover the original time signal. So, the hypothesis for this project is to use the frequency domain method to extract the noise using DASYLab® software.

## 1.6. SCOPE

The scopes of the project are limited to:

i. Record vibration signals at different type of frequency.
ii. Frequency domain analysis to extract noise from the signals.
iii. Optimization of the noise extraction.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1. INTRODUCTION

This chapter discussed about suspension system, signals analysis, time domain analysis, frequency domain analysis and noise.

## 2.2. SUSPENSION SYSTEM

According to Donald Bastow *et. al.* (2004), the word suspension is the term given to the system that contains spring, shock absorbers and linkages that connects a vehicle to wheels. Suspension system isolates the people or cargo from severe levels of vibration and shock induced by the road surface. This isolation from road-induced shock and vibration is very important to improves and increase the longevity and durability of the vehicles. Figure 2.1 shows the suspension system in a vehicle body. The suspension basically includes the springs, damper and the wheel axle.

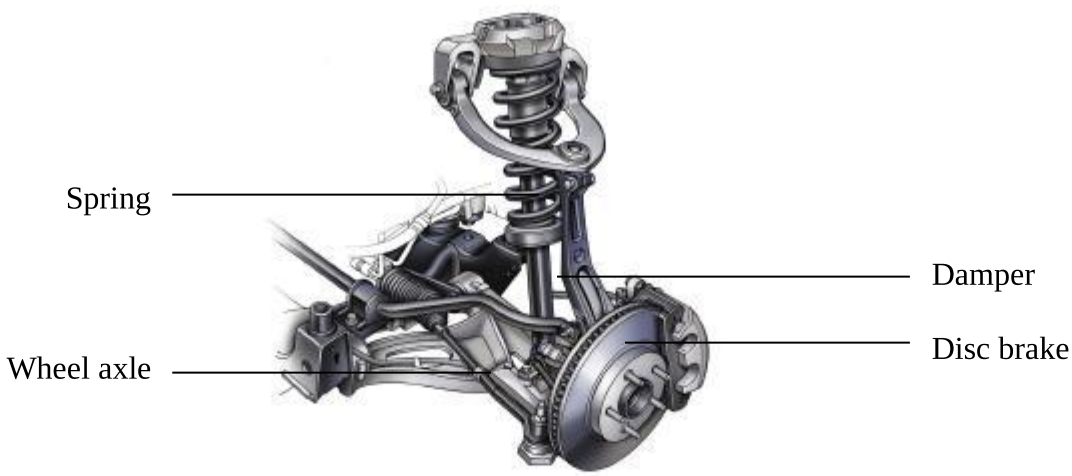


**Figure 2.1:** Suspension system on the vehicle

Source: Charles C. Roberts, Jr. (2005)

According to Selim Hasagasioglu *et. al.* (2011), the suspension system also enables the wheels to maintain contact with the road surface, assuring the stability and control of the vehicle because all the forces acting on the vehicle do so through the contact patches of the tires. The suspension system is an important factor in determining the comfort of a car because the suspension system is the pivot between the wheels with the weight of the car and also serves to dampen shocks and engine sound. In other words, the job of a vehicles suspension is to maximize the friction between the tires and the road surface, to give the stability of handling the vehicles and to provide the comfort of the passengers. If the road is flat with no irregularities, the suspension maybe might not be possible. But the flat road can said to be impossible. It's means that the suspension was very important part in order to reduce the effect regarding to the flatness of the road surface. In Figure 2.2 show the basic concept of a suspension system. The suspension basically main objective is to supporting the sprung mass and the unspring mass.

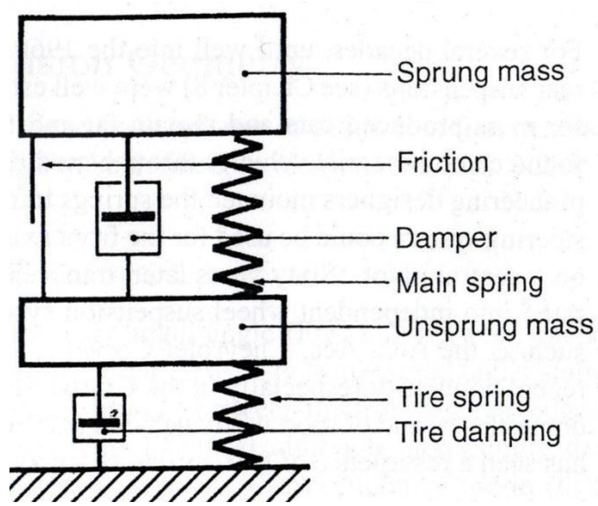


**Figure 2.2:** Basic elements of suspension system

Source: Donald Bastow, (2004)

A bump or subtle imperfections on the road surface causes the wheel to move up and down perpendicular to the road surface. In this situation, the vehicles can be loose handle and make the driving unsafe. This time, the suspension can play its role that ensure the tires always contact with the road surface and maintain the control over the vehicle and drive it safely. The suspension is located at the wheels of the vehicles. So, the most important thing to consider while building a suspension is the suspension is used to support a load from above such as the body of the vehicles, the loadings, the passengers and so on. The spring is what actually support the weight of the vehicle and will determine how the vehicle's weight changes when braking, acceleration and cornering.

According to Singiresu S. Rao (2004), when building a suspension, three most crucial elements must be considered. The first thing is flexibility. It is refers to designs of the suspension system that can adapt or giving the good respond to potential internal or external changes affecting its value delivery. Flexibility is given by a spring (on the suspension system) that distort and recovers (typically compress and expands) as the wheel traverses disturbances in the road surface. The second thing is damping which is essentially to restrain the body and wheel resonant bouncing motions. Damping is defined as the mechanism by which the vibrational energy is gradually converted into heat or sound. The damper also assume to have neither mass nor elasticity, and damping force exists only if there is relative velocity between the two ends of the dampers and the third one is the location of the wheel.

### 2.2.1. The Principle of Suspension System

According to Keith Worden *et. al.* (2008), the vehicle suspension systems basically consist of wishbones, the spring, and the shock absorber to transmit and also filter all forces between body and road. The task of the spring is to carry the body-mass and to isolate the body from road disturbances and thus contributes to drive comfort. Table 2.1 discusses the suspension component, properties (composition and position) and its function. The damper contributes to both driving safety and comfort. Its task is the damping of body and wheel oscillations, where the avoidance of wheel oscillations directly refers to drive safety, as a non-bouncing wheel is the condition for transferring road-contact forces. Considering the vertical dynamics and taking into account the vehicle's symmetry, a suspension can in a first step be reduced to the so-called quarter-car model as shown in Figure 2.3. Here, elements for modeling the Coulomb friction and an additional force resulting from active or semi-active components are added. The tire is typically modeled by a single spring.

The terms of driving safety and comfort are defined. Driving safety is the result of a harmonious suspension design in terms of wheel suspension, springing, steering and braking, and is reflected in an optimal dynamic behavior of the vehicle, whereas driving comfort results from keeping the physiological stress that the vehicle occupants are subjected to by vibrations, noise, and climatic conditions down to as low a level as possible. It is a significant factor in reducing the possibility of miss actions in traffic. Typically, the acceleration of the body as an obvious quantity for the motion and vibration of the car body and the tire load variation as indicator for the road contact are used for determining quantitative values for driving comfort and safety, respectively.

**Table 2.1:** The examples of components of automotive system

| Component | Properties | Function |
|---|---|---|
| **Shockbreaker** | This component is made of steel so that it has more endurance and strength. However Shock breaker seriring will wear with time or usage period and the use of inappropriate. | These devices served to absorb shocks when the car drove and bulldoze variety of track conditions. Shock breaker made of steel that assists the spring or as to support the weight of the car following the charge that he had plundered. |
| **Arm bushing** | This form of rubber suspension components is located at the fulcrum between the wheels and arms clamp. | Bushing duties dampen vibration at the connection between the components of the suspension of the metal. When the car is often bulldoze the streets potholes or broken street, which is sustained load device, is also increasingly heavy. |
| **Tierod and balljoint** | Tierod, tierod end and balljoint is made of metal material | Tierod has a continuing function of the steering wheel turning force to the wheels. While balljoint useful to sustain Knuckle arm. |

Source: Recent patents on mechanical engineering, (2008)

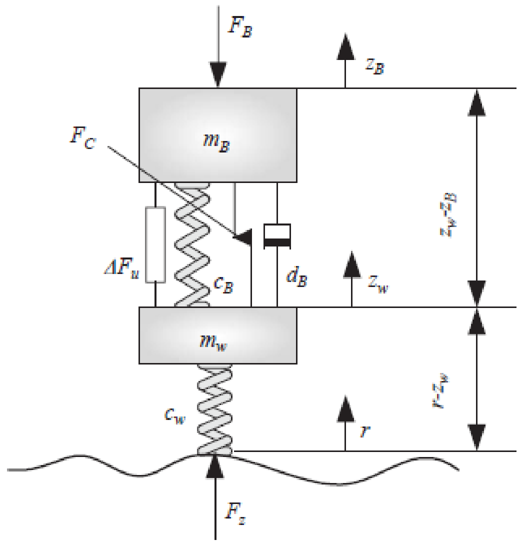


**Figure 2.3:** One-Dimensional Vertical Vehicle Representation the Quarter Car Model

Source: Shaohua, (2003)

## 2.3. SIGNALS

According to A.G. Ambekar (2006), signal is a series of numbers that come from measurement, typically obtained using some recording method as a function of time. A signal can be extracted from many sources such as vibrating machines, sound and movement. All these cause unbalance, misalignment, and looseness, dry friction between two rubbing surface, wind-induced vibration (self-induced vibration), oil whirl and external excitation. Some wavelength as contains high frequency and some contains low frequency waveform. The signal we have from experiment have disturbance such as noise.

### 2.3.1. Signal Characteristic

Signal characteristic always perform in vibration signal, below this show some of characteristic of signal in vibration.

i. Some features have a long time duration but narrow bandwidth, for example, rub & buzz noise.
ii. Some features have short time duration but wide bandwidth, for example, spikes and breakdown points.
iii. Some features have a short time duration and narrow bandwidth, for example, decayed resonance.
iv. Some features might have a time-varying bandwidth, for example, the imbalance bearing generating noise dependent on RPM.

### 2.3.2. Types of Signals

Signal analysis is fundamental to vibration testing. Consequently, understanding it and its proper use should be high priority to any practioner. Dynamic signal from a data analysis viewpoint, divide time history signals into two broad categories, each with two subcategories which are:-

a. Deterministic data signals:-
   i. Steady-state or periodic signals.
   ii. Transient signals.

b. Random data signals
   i. Stationary signals.
   ii. Non-stationary signals.

According to John Wiley & Sons (1987), the chaotic signal is recently recognized phenomenon where a random appearing signal is controlled by a deterministic process. Chaotic signals are receiving more attention in an effort and analyze them. Just how this research will impact future signal classification is not clear at this time; thus, the question marks in the diagram. However, it must be recognized that some random appearing signal analysis purpose until ways are found to clearly distinguish chaotic signal analysis purpose until ways are found to clearly distinguish chaotic signal from random signals. Chaotic signal are not considered in this book beyond cursory reference to them. In Figure 2.4 show the dynamic signals are generally classified as deterministic and random.

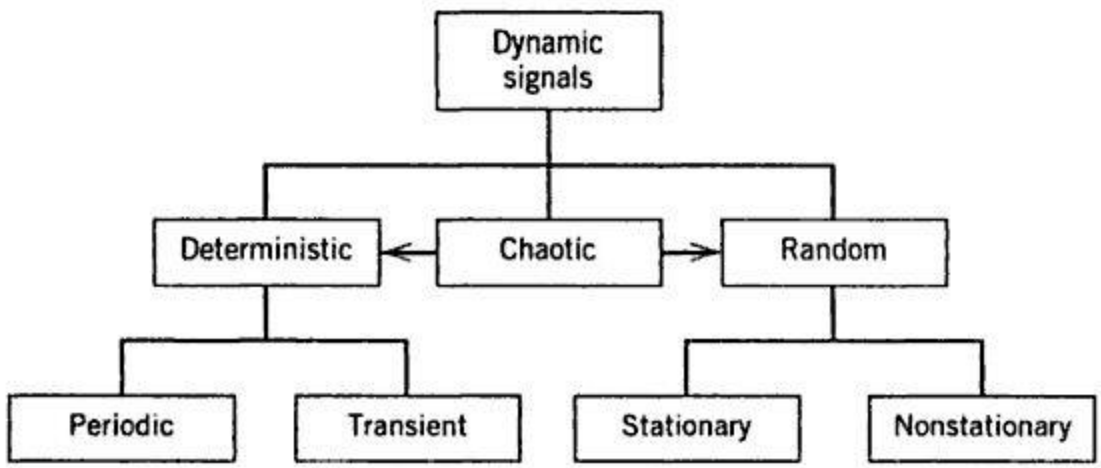


**Figure 2.4:** Dynamic signal classification

Source: Vibration testing theory and practice, (1995)